Dancing in the Dark: Evolutionary Psychology and the Argument from Design

Karola C. Stotz

Center for Philosophy of Science,

University of Pittsburgh,

817 Cathedral of Learning,

Pittsburgh PA 15260 USA

Paul E. Griffiths

Department of History and Philosophy of Science,

University of Pittsburgh,

1017 Cathedral of Learning,

Pittsburgh PA 15260 USA

1   Evolutionary Psychology and its Critics

1.1 Convenient Enemies

The Narrow Evolutionary Psychology Movement represents itself as a major
reorientation of the social/behavioral sciences, a group of sciences previously dominated
by something called the 'Standard Social Science Model' (SSSM; Cosmides, Tooby, and
Barkow, 1992). Narrow Evolutionary Psychology alleges that the SSSM treated the mind,
and particularly those aspects of the mind that exhibit cultural variation, as devoid of any
marks of its evolutionary history. Adherents of Narrow Evolutionary Psychology often
suggest that the SSSM owed more to ideology than to evidence. It was the child of the
1960s, representing a politically motivated insistence on the possibility of changing social
arrangements such as gender roles:

> 'Not so long ago jealousy was considered a pointless, archaic institution in need
> of reform. But like other denials of human nature from the 1960s, this bromide
> has not aged well.' (Stephen Pinker, endorsement for Buss, 2000))

This view of history does not ring true to those, like the authors, who have worked in
traditions of evolutionary theorizing about the mind that have a continuous history
through the 1960s and beyond: traditions such as evolutionary epistemology (Stotz, 1996;
Callebaut and Stotz, 1998) and psychoevolutionary research into emotion (Griffiths,
1990,1997).

The two research traditions that looks most like the supposedly dominant SSSM are
behavior analysis in psychology and social constructionism across the social and
behavioral sciences generally. Behaviorism was indeed a dominant paradigm in the
classic sense until the late 1950s, but it has been in continuous retreat ever since. Social
constructionism has excited widespread interest ever since its origins in the work of Peter
Berger and Thomas Luckmann (Berger and Luckmann, 1967), but it has only ever been
the received view in sub-fields of certain disciplines, such as cultural anthropology. In

experimental psychology and cognitive science, the two fields that Narrow Evolutionary Psychology is most concerned to reform, social constructionism has never achieved any kind of dominance. Furthermore, contrary to the impression given by Narrow Evolutionary Psychology, the tradition of psychoevolutionary research in the social and behavioral sciences is a more or less continuous one leading back through the sociobiology and Darwinian anthropology of the 1970s to the longstanding program of human ethology whose approach was laid down by Konrad Lorenz and Niko Tinbergen and whose best known representative is perhaps Irenaus Eibl Eibesfeldt. Thus, what Narrow Evolutionary Psychology represents as monolithic 'old' and 'new' approaches to the mind are better seen as longstanding oppositions between and within various disciplines and sub-disciplines in the human sciences. The central feature of the SSSM, the idea that most psychological mechanisms are 'general-purpose' or 'content-independent', is something many earlier theorists have criticized. Contrary to its publicity, Narrow Evolutionary Psychology is not 'the new science of the mind': the inevitable result of finally putting Darwinism to work in the realm of human affairs. Instead, it is the conjunction of two longstanding research traditions, neither of which is the only viable option in its own field. These traditions are the classical, representational program in cognitive science (Marr, 1982; Fodor, 1983) and the adaptationist form of neo-Darwinism that informed '70s sociobiology and was popularized by Richard Dawkins (Dawkins, 1976).

In this paper we argue that Narrow Evolutionary Psychology inherits the worst failings of both of its constituent programs. Its methodology is unsuitable either for making heuristic predictions about mental structure that can guide psychological research or for providing deep, naturalistic explanations of mental structure. On a more optimistic note, we offer a more workable alternative way to garner the heuristic benefits of a biological perspective for psychological research and sketch some of the elements that will have to be added to the version of evolutionary theory favored by Narrow Evolutionary Psychology in order to construct fully naturalistic explanations of mental structure.

1.2 The Evolution of Cognition: A Commitment to Darwinism

One result of the historical story that accompanies Narrow Evolutionary Psychology is an unfortunate tendency to treat all critics of the movement as opponents of evolutionary psychology in general, or even of the theory of evolution itself. We want to make it clear that we are neither. We are committed to seeking a *naturalistic* account of cognition, one that makes mental processes part of the natural world and their investigation part of natural science. This implies that cognition must have evolved like any feature of living systems. A fully naturalistic perspective, however, requires more that mere consistency with some model of evolution. Naturalism requires that both the model of cognition and the model of evolution are themselves devoid of any essential commitments that cannot be given a natural explanation. The models must be:

1. Mechanistic

The entities and processes postulated by the models must be either processes that feature in lower-level ('physical') theories, or emergent, system-level properties whose emergence can be causally explained in terms of lower-level processes. A good example of this second sort of explanation is the emergence of structure, such as attractors and bifurcations, in the dynamics of complex systems. This structure is emergent in the sense that it cannot be predicted from or reduced to regularities governing the activity of the systems components. The fact that an unpredictable dynamical structure emerges, however, can be fully explained in terms of regularities governing the system components. No mysterious extra ingredient is required. In the present context, a key implication of mechanism is that functional and design language must be able to be exhaustively 'discharged' in mechanistic terms. That is, the fact that biological systems can be discussed in those terms must be mechanistically explained in much the same way that system dynamics can be mechanistically explained.

In the context of biology and cognition, it is also critical to notice that the quest for explanatory continuity does not imply the traditional 'reduction' of the social to the individual and the individual to its parts. The contextual conditions under which systems

operate are as legitimate a source of explanation as the intrinsic properties of system components. The tendency of an asexual species to remain in one region of phenotypic space, for example, can be explained in terms of the canalized developmental structure of individual organisms or, equally legitimately, in terms of the constraints imposed on the species by selection. The more 'internal' explanation is not intrinsically preferable to the more contextual explanation. In the same way, human development proceeds in a rich, 'developmental niche' constructed by previous generations, and the constraints imposed by this niche are a legitimate source of explanation of species-typical traits.

2. Historical

Naturalistic models of cognition and other features of biological form must be consistent with the historical emergence of these features over time. Historical explanations that depend on the presence of unique sets of conditions presented in the correct sequences are not less satisfactory than explanations using general laws that apply across a wide range of initial conditions. In fact, the nature of biological systems provides reasons to expect historical explanations to be prevalent. Biological species are historical lineages capable of unlimited evolutionary change, not natural kinds of organisms, and so do not feature in traditional, universal laws of nature (Hull, 1984; Griffiths, 1999). The best candidates for traditional laws in evolutionary theory are ecological generalizations in which species and populations figure only as instances of ecological kinds, such as 'primary producer' or 'current occupant of patch' (Hull, 1987). But the output of processes governed by these ecological laws and generalizations is typically sensitive to the initial conditions of the process, so the resultant explanations are likely to be historical in nature (O'Hara, 1988).

3. Developmental

A naturalistic model of an evolved trait must allow a mechanistic understanding of the development of that trait both in ontogeny and in its original occurrence as an 'evolutionary novelty'. It has been recognized since Darwin himself that the theory of natural selection requires a theory of heredity and variation. We argue below that a mere

reference to gene transfer and random mutation fails to discharge this explanatory obligation. Reference to genetic information and a genetic program are still less satisfactory, since the literal genetic code is only concerned with protein structure and the broader uses of these terms are nothing more than a promissory note to be paid later with a full, mechanistic account of developmental biology. That is why molecular genetics and molecular developmental biology are important to contemporary evolutionary theory: they supply elements of the evolutionary process that have previously had to be assumed. As well as filling a gap in our understanding of evolution, the particular way in which the gap is filled will have implications for evolutionary theory, as is manifest in the upsurge of interest in 'evolutionary developmental biology'.

A dominant theme of the rest of this paper will be the need to consider organisms as situated in a natural environment. In different ways, this is the key to meeting all three of the obligations we have outlined. Mechanistic explanations of complex systems typically require as much attention to the constraints imposed on those systems by their context as to the constraints imposed by their constituents. The sorts of historicized evolutionary explanations that we have described above are contextual in this way: they attend to the historical conditions in which the organism evolved. Finally, the explanatory strategy in developmental biology most likely to leave promissory notes scattered about is one that localizes control of development in a single material resource. Single causes in development derive their specific effects from the context in which they operate. While it can be a useful experimental tactic to treat this context as given, this tactic achieves experimental tractability precisely by sacrificing explanatory completeness.

In the next section we outline the problem that Narrow Evolutionary Psychologists suggest is the primary impediment to progress in cognitive science and the solution that they offer to this problem. In section three we argue that this solution is unlikely to work and that a more promising alternative is readily available. In section four we turn to the account of evolution presupposed by Narrow Evolutionary Psychology and argue that it needs to be enriched in various respects before genuinely naturalistic explanations of mental processes are possible.

2. Cognitive Science in the Dark?

But in many branches of the psychological and behavioral sciences it is today quite usual to devise, out of hand, some sort of experimental procedure, apply it to a highly complicated system about which next to nothing is known, and then record the results. Of course, information can be, and has been gathered by this method… However…we prefer to have results before the present interglacial period comes to an end. That is why ethology emphatically keeps to well-tried Darwinian procedures. (Lorenz, 1966, p. 274)

Practitioners [of anthropology, economics, and sociology have to] realize that theories about the evolved architecture of the human mind play a necessary and central role in any causal account of human affairs. …Cognitive scientists will make far more rapid progress in mapping this evolved architecture if they begin to seriously incorporate knowledge from evolutionary biology and its related disciplines … into their repertoire of theoretical tools, and use theories of adaptive function to guide their empirical investigations. (Tooby and Cosmides, 1998, p. 195)

In essence, the critique of current cognitive science offered by Narrow Evolutionary Psychology is the same as Konrad Lorenz's earlier complaint against what he liked to call 'the American behaviorists'. A complex device like the human brain exhibits an extraordinary number of regularities, but only some of these can properly be construed as facts about how the mind *works*. The vast majority of regularities are mere side effects and are not useful entry points to a systematic understanding of the principles according to which the system operates. Without an evolutionary perspective, psychological science is groping in the dark. It does not know what it is looking for and when it finds something it does not know what it is looking at. To Lorenz, the laboratory-based search for laws of behavior seemed as misguided as dropping automobiles from buildings under controlled conditions in order to 'discover the principles governing their operation'. In the same

vein, advocates of Narrow Evolutionary Psychology argue that empirical psychology without an evolutionary perspective has no way to determine whether it is studying meaningful units of behavior or mental functioning. The fundamental idea behind Narrow Evolutionary Psychology is that the natural way to classify behavior and the cognitive functioning that underlies behavior is in terms of adaptive design:

> The intellectual payoff of coupling theories of adaptive function to the methods and descriptive language of cognitive science is potentially enormous. By homing in on the right categories -- ultimately adaptationist categories --an immensely intricate, functionally organized, species-typical architecture can appear … Just as one can flip open *Gray's Anatomy* to any page and find an intricately detailed description of some part of our evolved species-typical morphology, we anticipate that in 50 or 100 years one will be able to pick up an equivalent reference work for psychology and find in it detailed information-processing descriptions of the multitude of evolved species-typical adaptations of the human mind, including how they are mapped onto the corresponding neuroanatomy and how they are constructed by developmental programs. (Tooby and Cosmides, 1992, p. 68-69)

2.1 Narrow Evolutionary Psychology: The Past and the Present

The form of evolutionary theory that figures in Narrow Evolutionary Psychology is continuous with that which gave rise to sociobiology, but the emphasis on cognitive mechanisms, as opposed to behavior, is new. In fact, sociobiologists criticized the earlier ethological tradition for explaining human behavior as the result of evolved mechanisms rather than focusing on the direct predictions of evolutionary theory about behavior itself. The latter approach had been adopted with considerable success by behavioral ecology during the 1960s, just as the ethologists' 'hydraulic model' of mental mechanisms was falling into disrepute. In behavioral ecology, behaviors were interpreted as evolutionarily stable strategies in competition between and within species. Models of these competitive interactions between organisms could be constructed using the new techniques of evolutionary game theory and the predictions of these models tested against actual behavior. Sociobiology simply sought to extend this successful approach to humans. It

was argued that sociobiology was superior to ethology because it made predictions about behavior and tested them rather than merely describing behavior and explaining it. This led to the hope that evolutionary models could guide psychological research and point it towards important phenomena that would otherwise be misunderstood or overlooked. The advocates of this new approach and proponents of these arguments included leading figures in today's Narrow Evolutionary Psychology, such as Jerome Barkow (Barkow 1979). Narrow Evolutionary Psychology has retained the idea that evolutionary theory can make predictions to assist the process of psychological discovery, but has become strongly critical of the sociobiological emphasis on behavior. According to Narrow Evolutionary Psychology, the current human environment is so different from that in which humans evolved that current behavior is unlikely either to be the same as the behavior produced in the past or to have the same effects on biological fitness. For these reasons, Narrow Evolutionary Psychology does not use evolutionary theory to predict which behaviors will be observed today or which behaviors will be adaptive today. Instead, evolutionary theory is used to predict which behaviors would have been selected in postulated ancestral environments[1]. Current human behavior is to be explained as the output of the mechanisms that evolved to produce those ancestral behaviors when these mechanisms operate under modern conditions. Narrow Evolutionary Psychology also adopts the idea that apparently very diverse behaviors may be the manifestations of a single, evolved rule under a range of local conditions, an idea which originated in 'Darwinian anthropology' (Alexander 1979; Alexander 1987). Refocusing research on the 'Darwinian algorithms' that underlie observed behavior, rather than the behavior itself lets the evolutionary psychologist 'see through' the interfering effects of environmental change and cultural differences to an underlying human nature (Figure 1).

Insert Figure 1. about here.

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[1] The simple contrast between earlier sociobiology and today's evolutionary psychology suggested here is a caricature that does not do justice to the earlier researchers, who were often very well aware of the point about environmental change. For an account of the historical development of sociobiological methods, see chapter 13 of Sterelny & Griffiths (1999).

Narrow Evolutionary Psychology argues that psychological mechanisms must be described using the representational, information-processing language of classical cognitive science. Behavioral descriptions cannot be used, for the reasons described above. Neurophysiological descriptions are an obvious alternative, as they correspond to the morphological descriptions given to other, evolved features of human anatomy; but the form of evolutionary theory preferred by Narrow Evolutionary Psychology will not predict anything about 'mechanisms' in this literal sense. The models used in behavioral ecology predict which behaviors will be selected but do not predict anything about how those behaviors will be produced. If we accept the conventional view in cognitive science that indefinitely many different neurological mechanisms could potentially support the same behavior, behavioral ecology predicts nothing about neurological structure apart from its output when supplied with input of the kind it received in the evolutionary past:

> When applied to behavior, natural selection theory is more closely allied with the cognitive level of explanation than with any other level of proximate causation. This is because the cognitive level seeks to specify a psychological mechanism's function, and natural selection theory is a theory of function. (Cosmides and Tooby 1987, p. 284)

What Narrow Evolutionary Psychology refers to as theories about 'psychological mechanisms' are more accurately described as theories of cognitive functioning – theories about the performance profile of the mind.

This fact about the output of adaptationist reasoning fits together neatly with the idea, usually attributed to David Marr (Marr, 1982), that explanation in cognitive science should proceed simultaneously at three, mutually illuminating levels. The highest level concerns the tasks that the cognitive system accomplishes – recovering the shape and position of objects from stimulation of the retina, for example. The lowest level concerns the neurophysiological mechanisms that accomplish that task – the neurobiology of the visual system. The intermediate level concerns the functional profile of those mechanisms, or as it is more usually described, the computational process that is implemented in the neurophysiology. The two higher levels of analysis are irreducible

because each level is multiply realizable at lower levels: the same task can be accomplished by different algorithms and the same algorithm can be implemented on different hardware. Redescription at a lower level thus results in a reduction in generality.

Insert Figure 2. about here.

Marr argued that adjacent levels of analysis are mutually illuminating and that research should be pursued simultaneously at all three levels. Hypotheses about the neural realization of the computational level constrain hypotheses about computational processes to those that can be realized by the proposed neural systems. Conversely, hypotheses about computational processes guide the interpretation of neural structure. It makes sense to look for structures that could perform the tasks that need to be performed. Similar relations of mutual constraint hold between the level of task description and the computational processes. But there remains something of a puzzle as to how the highest level, the task description, is to be specified, other than by stipulation. It seems obvious that the task of vision is to reconstruct the surrounding objects but why is this the right answer? Why is color vision an aid to object recognition, rather than the overall aim of vision being aesthetic experience and object recognition only a means to that end? Why are visual illusions not the *non plus ultra* of visual well-functioning? This is essentially the problem of providing a natural taxonomy of cognitive function that was encountered above. The value of evolutionary theory to cognitive science has been described in many ways in the Narrow Evolutionary Psychology literature, but all of these come down to the same thing: it provides the task description and thus constrains lower-level hypotheses (Figure 3). The purpose for which an organism has been designed by natural selection is the task description of that organism and the sub-tasks correspond to separate adaptive challenges posed by the ancestral environment:

Evolutionary psychologists expect to find a functional mesh between adaptive problems and the structure of the mechanisms that evolved to solve them. (Cosmides, et al., 1992, p. 7)

Because the enduring structure of ancestral environments caused the design of

psychological adaptations, the careful empirical investigation of the structure of

environments, from a perspective that focuses on adaptive problems and outcomes,

can provide powerful guidance in the exploration of the mind. (Tooby and Cosmides

1992, p. 72)

Insert Figure 3. about here.

2.2 Massive Modularity

One of the best-known aspects of Narrow Evolutionary Psychology is the 'massive

modularity thesis', according to which the mind has few if any domain general cognitive

mechanisms. Instead, the mind is a collection of separate 'modules' each designed to

solve a specific adaptive problem, such as mate-recognition or the enforcement of female

sexual fidelity. The massive modularity thesis is the result of reasoning from a very

general claim about selection pressures to a very general conclusion about the structure of

the mind. Narrow Evolutionary Psychology claims that evolution would favor multiple

modules over domain general cognitive mechanisms because each module can be fine-

tuned for a specific adaptive problem. Hence, it is argued, cognitive scientists should look

for domain specific effects in cognition and should conceptualize their work as the search

for and characterization of mental modules.

3. Enlightenment from Evolution?

In this section we argue that the proposed evolutionary heuristic for cognitive science –

the use of evolutionary task descriptions to constrain theories of cognitive function – is

unworkable. Fortunately, another heuristic, familiar from actual practice in other areas of

functional anatomy, is available.

The idea that knowledge of evolutionary functions can act as a guide to research into

cognitive functioning faces an obvious objection. It would seem at first glance that

knowledge of the selection pressures in distant evolutionary episodes is even harder to come by than knowledge of current cognitive functioning. Evolutionary function is an epistemically demanding concept, one whose disciplined application requires considerable research and which, even then, typically remains highly inferential and subject to frequent reappraisal (Brandon, 1990, Ch. 5; Lauder, Armand, & Rose, 1993). The actual functioning of cognitive systems, however, is an empirical matter about which we can gain experimental knowledge. Moreover, evolutionary functions are *unusually* hard to establish in the case of cognitive functioning. As described above, Narrow Evolutionary Psychology denies that current behaviors and their ecological effects are good evidence for the evolutionary functions of the mechanisms that underlie those behaviors. Thus, while most behavioral ecologists can conduct empirical tests of fit between observable behavior and the predictions of an evolutionary model, Narrow Evolutionary Psychology is forced to interpose between the observation and the prediction a model of the psychological mechanism that produced the ancestral behavior. This second psychological model is used to predict which behavior will occur under modern conditions. It is this prediction that is tested against empirical data. A huge hypothetical apparatus thus separates the data from the model under test and, as always, the test is only as reliable as the assumptions that went into building that apparatus. A further difficulty is that behavioral ecologists are typically able to base their evolutionary models on empirically derived knowledge of the relevant ecology. Narrow Evolutionary Psychology must base its models on reconstructions of past ecologies from paleontological and comparative data.

There is a still deeper problem, which we believe is more or less fatal to the proposed evolutionary heuristic. Narrow Evolutionary Psychology presumes that evolutionary theory can guide psychological research because it can model the selection pressures that led to the evolution of traits *about which we lack current descriptive knowledge*. But, as we will now show, the ability to model selection pressures is directly proportional to current descriptive knowledge of the form of trait. The heuristic will only work where it is not needed! Narrow Evolutionary Psychology argues that knowledge of evolutionary function is a guide to the actual form of the mind because:

In evolved systems, *form follows function*. The physical structure is there because it embodies a set of programs; the programs are there because they solved a particular problem in the past. (Tooby and Cosmides, 1997, p. 13, our emphasis)

The idea is that evolutionary theory can reconstruct the niche in which the human mind evolved and predict how the mind will be structured to fit that niche. More precisely, the evolutionary theorist will take the complex property of occupying the niche and conduct a functional analysis of that property akin to the functional analysis of the mind described above. The property of occupying the niche can be thought of as the organisms 'lifestyle' (e.g., living in a tropical forest eating insects that live under the bark of trees). This lifestyle consists of separate tasks (getting up the trees, finding the insects, extracting the insects, and so forth). Having created this task description the theorist can predict that the organism will have mechanisms that allow it to get up the tree, mechanisms that allow it to find the insects and mechanisms that allow it to extract them from under the bark. In the same way, it is proposed, we can take the niche that the human mind evolved to occupy and functionally analyze the property of occupying that niche in order to determine the (functional) structure of the mind.

The trouble with this proposal is that it assumes that we can reconstruct the niche while we are ignorant about the structure of the mind. The problem facing Narrow Evolutionary Psychology is quite unlike that facing the student of tropical woodpeckers, who can identify the relevant niche empirically. It is also unlike that of the paleontologist, who knows the form of the woodpecker from the fossil record. What Narrow Evolutionary psychologists propose to do is more like a paleontologist who has found fossil birds with no skulls and proposes to reconstruct their feeding mode by thinking about the niche they occupied. The problem, of course, is that the best way to reconstruct their niche would be to look at their beaks and determine for what tasks beaks like that are good. Narrow Evolutionary Psychology has overlooked the conceptual relationship between an evolutionary niche and the organism that fills it. An evolutionary niche is a hyperspace whose axes are ranges of tolerance for ecological parameters, parameters that range from

rainfall to predator density. A simple volume of physical space contains innumerable, overlapping niches. To determine the niche of any given species it is necessary to know what ecological parameters the species responds to and in what range of those parameters a population of that species can maintain itself. The more that is known about an organism, the more precisely it is possible to state the dimensions and extent of its niche. The 'woodpecker' niche described above is laughably underspecified if the aim is to explain form. It is indeed occupied by woodpeckers in Borneo and Sumatra, but in New Guinea this niche is occupied by arboreal marsupials (Brandon, 1990, p. 67-68). If our evolutionary predictions about cognitive function are so imprecise as not to distinguish the psychological equivalents of flying and climbing they will not be of any great value to cognitive science. We will suggest in section four that in order to make evolutionary predictions of the necessary precision it would be necessary to know not just a great deal about form, but also a great deal about development, since development determines the class of 'solutions' that are available for selection.

Given the difficulty of analyzing evolutionary function in the absence of descriptive anatomy, it is reassuring to note that structural anatomy, and to a lesser but still considerable extent functional anatomy, made great strides before Darwin. In his work on the emotions, for example, Darwin relied on knowledge of the function of the facial muscles in emotional expression derived from the longstanding study of facial anatomy by artists and physicians. Functional anatomy is an important comparison case for Narrow Evolutionary Psychology, as it is the equivalent for other organs of the cognitive level of analysis of brain function that Narrow Evolutionary Psychology aims to bring into being. Functional anatomy describes the specific tasks performed by anatomical structures, tasks that could, at least in principle, be performed by other physical structures. Even after the widespread acceptance of Darwin's theory it is unclear that evolutionary functional analysis has played a major role in functional anatomy. That is not to say that an evolutionary perspective has not been important. The comparative method has been recognized as one of the keys to progress in anatomy since the renaissance, and this method is on a firmer footing once taxonomy is based on evolutionary relationships. There are other relevant aspects of an evolutionary

perspective too, as we will show below. But the predominant notion of function in functional anatomy does not seem to be evolutionary function (teleonomy). One observation in support of this idea is that scientists elucidating anatomical and physiological function do not experience a major discontinuity in their research practice when they move from those features that can plausibly be supposed to be adaptations to those that are 'nothing but spandrels, chemistry and entropy' (Tooby and Cosmides, 1998, p. 195). For example, some of the pairings between codons and amino acids that make up the genetic code and its variants are probably the result of selection for error minimization, whilst others are vestiges of chemical affinities in RNA world and other reflect the temporal sequence in which new amino acids became available for inclusion in polypeptides (Knight, Freeland, & Landweber, 1999). Yet exactly the same research practices will reveal the function of all these codons – what they code for - because a codon's function is a matter of what the codon actually does and not why it does it. Similarly, anatomists do not usually withdraw claims about the functions of anatomical structures when presented with evidence that these are not the functions in virtue of which the structure was selected. The distinction between functions and mere effects, so critical to the evolutionary concept of function, does not seem critical for the practice of functional anatomy and physiology, or to the anatomical/physiological concept of function. This should not be surprising, since the evolutionary notion of function actually presupposes that the same functions can be identified in a way that says nothing about their evolution. The evolutionary functions of a trait are the ways it contributed to the fitness of ancestral organisms, that is to say, they are the functions assigned to the trait by a causal functional analysis of how those ancestral organisms survived and reproduced (Griffiths, 1993). The causal functional analysis of fitness is no different from the causal analysis of any other property of an organism, such as disease susceptibility: it merely identifies what the parts do in the overall causal mechanism. Ronald Amundson and George Lauder have discussed these issues in more detail and conclude that the predominant notion of function in the anatomical sciences is causal role function: the contribution made by a part of a mechanism to the causal capacity of the mechanism of which it is a part (Amundson and Lauder, 1994).

We have argued that evolutionary functional analysis is too epistemically demanding to provide a short cut to understanding cognitive function and that other fields of functional anatomy do not rely on evolutionary functional analysis. But the problem identified by Narrow Evolutionary Psychology, and by ethologists like Lorenz, remains. The mind is an unusually complex system whose structure-function relationships are hard to determine. It would be profoundly useful to have a natural taxonomy of cognitive function to constrain hypotheses about function and to provide a structure within which to place empirical findings about function. Fortunately, there is an alternative source of such a natural taxonomy and, indeed, it is the one the ethologists originally had in mind.

Niko Tinbergen famously proposed that there were four questions that could be asked about any behavioral trait (Tinbergen 1963):

1. What is the evolutionary history of the behavior?
2. What is the current use of the behavior in the life of the organism?
3. How does the behavior develop over the life of the organism?
4. What psychological and other mechanisms control the behavior?

The four questions correspond to four explanatory projects in biology. The first, evolutionary, question is answered by phylogeny reconstruction and evolutionary modeling. The second question is an ecological one: it asks how the trait contributes to the organisms' capacity to occupy its niche. There is a third question for developmental biology and a fourth for the cluster of anatomical and physiological disciplines, a cluster that includes experimental psychology and cognitive science.

We have described the similarity between Narrow Evolutionary Psychology and Lorenz's view that the units of behavior studied by behavior analysis in the first half of the twentieth century were biologically meaningless and thus not a useful guide to the principles according to which the mind works. Unlike Narrow Evolutionary Psychology, however, Lorenz did not suggest that psychologists tackle Tinbergen's first question and try to reconstruct evolution. He suggested that psychology tackle the second question and try to understand the ecological significance of behavior. In the context of animal behavior studies this amounted to studying behavior in something approximating a

natural setting so as to be able to devise 'ecologically valid tasks' for later, controlled experimentation. In effect, the ethologists recommended using an ecological taxonomy of behavior to structure research on behavior. We suggest that an ecological taxonomy of cognitive function can play the same role for cognitive science. The study of cognitive functioning can be illuminated by the causal functional analysis of the capacity of the mind to occupy its *current* niche. Interestingly, this comes close to some of the methodological practices adopted by current research in situated activity or 'embodied mind' research (Hendriks-Jansen, 1996: Chapter 14).

We expect that adherents of Narrow Evolutionary Psychology will regard this as a ridiculous proposal - surely any meaningful account of an organism's relations with its environment must classify the animals' activities in terms of their adaptive function! But a moment's thought reveals that this picture is back-to-front. Theories of adaptive origins are generated by conducting a causal functional analysis of the capacity of the organism to survive and reproduce in an ancestral environment. The adaptive function of a trait *is* the function it is assigned in that analysis of *pure causal* function. If organism-environment relations cannot be understood unless the traits of the organisms are classified in terms of their adaptive function, then the entire enterprise of adaptive explanation cannot get started. So a purely causal analysis of the ecological function of behavior *must* be possible without knowing its adaptive function. But the idea that there are coherent concepts of function other than evolutionary adaptive function seems to be very hard for Narrow Evolutionary Psychology advocates to assimilate.

4   A Step-by-step Naturalization of Evolutionary Psychology

The model of evolution used by Narrow Evolutionary Psychology is the received view that came out of the 'modern synthesis' of Mendelian genetics and natural selection (Figure 4.). This section attempts to enrich the model of evolution employed by Narrow Evolutionary Psychology by adding some basic ingredients of naturalism to make it mechanistic, historical and developmental (see Section 1.2, above).

Insert Figure 4. about here.

We discuss a number of respects in which the traditional neo-Darwinian model of evolution fails to meet these desiderata. 1) It talks about form without having a theory of its genesis. 2) It expects a smooth fitness landscape for the mechanisms of mutation, sexual recombination, and selection to work upon, but has no explanation of the landscape itself. 3) It neglects important aspects of inheritance and makes the fact that humans have a high degree of cognitive flexibility and a complex system of cultural inheritance into an anomaly to be explained away. Finally, 4) it insists on selection as the 'sole entropic force in nature' and ignores the other, well-established entropic forces whose existence is a precondition for selection to produce order.
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4.1 Variation: The Origin of Form and Novelty in Evolution

> Natural selection depends on sorting through variants. Central to this kind of explanation is the historically realized sequence of variants. Selection shares explanatory force with the dynamics of variation. (Ahouse, 1998, p. 372)

> Darwin's theory of evolution is a theory of descent with modification. It does not explain the genesis of form, but the trimmings of the form, once they are generated. (Kauffman, 2000, p. x)

There is a glaring gap in Figure 4.: there is no reference to developmental biology or a theory of organization. Until this gap is filled, the model lacks an account of where phenotypes come from – an "evolutionary biology of organismic design" (Wagner, 1994, p. 276). In the adaptationist tradition, phenotypic variation is recognized as one of the main requirements of evolution, but its existence is rarely questioned or problematized. The capacity of developmental systems to generate variant forms that can solve adaptive problems enters the model only at the genetic level with the reference to mutation and recombination. There are well-known historical reasons for this. The 'modern synthesis' of Mendelian genetics and natural selection that put so many of the biological sciences on

a common theoretical basis failed to include the science of developmental biology (Hamburger, 1980). The synthetic theory bypassed what were at the time intractable questions of the actual relationship between stretches of chromosome and phenotypic traits. Although it was accepted that genes must, in reality, generate phenotypic differences through interaction with other genes and other factors in development, genes were treated as 'black boxes' that could be relied on to produce the phenotypic variation with which they were known to correlate. The black-boxing strategy allowed the two tractable projects – theoretical population genetics and the study of selection at the phenotypic level – to proceed. Population genetics, the mathematical core of the modern synthesis, could postulate genes corresponding to phenotypic differences and track the effect of selection on these phenotypic variants at the genetic level. Selection could be studied at the phenotypic level on the assumption that variant phenotypes were generated in some unknown way by the genes and that phenotypic change would be tracked by change in gene frequencies. Within this framework, the only account that can be given of phenotypic variation is that it corresponds directly to mutation and recombination at the genetic level. Any actual structure to development, resulting from the processes hidden in the 'black box', will reveal itself only in the failure of selectionist reasoning based on the 'null hypothesis' that no such structure exists. Like other pure adaptationist research programs, Narrow Evolutionary Psychology uses development only in this way, post hoc, to explain the lack of fit between a selective model and the data.

The continued exclusion of developmental biology from the evolutionary synthesis in favor of the genetic program metaphor, however, can only be regarded as a 'theoretical error of the first order' (Strohman, 1997). The methodological limitations that necessitated the black box approach to the gene have now been overcome, largely as a result of the molecular revolution. The vibrant field of evolutionary developmental biology has created a positive role for developmental biology in evolution: developmental biology explains where phenotypes come from and, in doing so, reveals the natural units of biological form. As empirical research on the formation and transformation of body plans has shown, ontogenetic pathways are not necessarily conserved along with the adult body plan (Raff, 1996). The same seems to be true with

respect to genetic mechanisms, which often fail to provide a reliable basis for a homology concept because of their loose correlation to morphological variation. It seems that structural homologues exist quasi-independently from their genetic and developmental causes (Wagner 1994,1995). Conversely, dramatic evolutionary changes in phenotypes can appear despite highly conserved patterns of genetic expression and processes of developmental organization (Mueller and Wagner, 1996). These findings support a view of homologies as "emergent stable patterns that can not be explained by stability at a more elementary level" (Wagner, 1995, p. 283). There seems to be a growing recognition that genomic sequence information is insufficient to determine the way gene products (proteins) interact to produce a mechanisms. In other words, genes in isolation contain insufficient information to determine gene function (Strohman, 1997).

The main focus of current research in evolutionary developmental biology is on major structural features of the body. In principle, however, the exact same approach should be applicable to the evolution of the mind. There have been some attempts to explore this possibility in the recent literature. Experiments and statistical analyses in neurogenesis conducted by Barbara Finlay and her colleagues (2001) found that few direct links could be made between the size of different brain structures and differences in behavior between species. Their findings suggest that, contrary to the widespread assumptions of structure/function relationship, increases in the size of individual structure may not be closely related to special behavioral capacities. The most useful predictor of structure sizes of individual brain structures is the sizes of other brain structures, with some additional minor effects of taxonomic relationship and overall brain and body size, suggesting that selection is, indeed, 'attacking a broader front'.

Even a complete analysis of the adult brain, using the full array of current techniques in neuroscience, will leave unexamined central questions about the essential relationship between structure and function. The study of development promises unique insights into the nature of functional architecture. Likewise, patterns of comparative brain evolution show structure/function links in a different light than that cast by any one species. The problem we concern ourselves with here, then, is

establishing the precise developmental substrate on which brain evolution selects. Do the brain and its information-gathering organs divide themselves up in evolution into components, modules, or circuits that can be the independent objects of special selection…? Or does selection attack a broader front, working change by adjusting the parameters of a "standard" developmental program? (Finlay, Darlington, & Nicastro, 2001, pp.4-5 of preprint)

We have referred to some of the new approaches to evolutionary explanation that are emerging from evolutionary developmental biology. The lesson to be drawn from these new approaches for evolutionary psychology is that the 'natural kinds' of behavior it seeks - and which Narrow Evolutionary Psychology claims to have found in innate and content rich, domain-specific modules - must be defined developmentally as well as functionally. Evolutionary psychology needs to account for the generation and fixation of traits. The real lesson which evolutionary theory has for psychology is that a synthesis is needed between behavioral ecology and developmental psychology - not evolutionary psychology, but evolutionary developmental psychology.

4.2 Evolvability conditions: Quasi-Independence and Continuity

The mechanisms of generation and fixation (or integration) are two steps in the direction of building stable units of characters. However, they are only two steps in the production of natural units of biological form. An essential third step in the production of *adaptive* developmental organization is the decoupling of previously integrated parts into quasi-autonomous units:

[The phenomena of adaptation] can only be workable if both the selection between character states and reproductive fitness have two characteristics: continuity and quasi-independence. Continuity means that small changes in a characteristic must result in only small changes in ecological relations: a very slight change in fin shape cannot cause a dramatic change in sexual recognition or make the organism suddenly attractive to new predators. Quasi-independence means that there is a great variety of

alternative paths by which a given characteristic may change, so that some of them will allow selection to act on this characteristic without altering other characteristics of the organism in a countervailing fashion; pleiotropic and allometric relations must be changeable. Continuity and quasi-independence are the most fundamental characteristics of the evolutionary process. Without them organisms as we know them could not exist because adaptive evolution would have been impossible. (Lewontin, 1978, p. 230)

Empirical evidence has shown that structurally or phylogenetically homologous characters can be the outcome of quite different developmental pathways (Hall, 1994; Wagner, 1994,1995; Wray & Raff, 1991; Bolker & Raff 1996) Even if we find similar patterns of ontogeny across different taxa these might turn out to be nothing more than 'crossing nodes' of developmental pathways coming from and going in quite different directions. Striking examples come in the form of directly developing amphibians that 'leap over' the usual larval stage or the apparent ease with which genus *Patriella* starfish species switch from producing small pelagic larvae to producing larger, directly developing benthic offspring (Palumbi, 1997). The concept that makes such phenomena consistent with the equally compelling evidence that developmental structure shapes variation is *developmental modularity*. Development is an integrated and integrative process as much as structures are interactively and hierarchically organized; yet structures as well as their underlying mechanisms can be decomposed into dissociable 'building blocks' (Brandon, 1999).

Two aspects are of importance, the *individualization* of characters allowing the free combination between individualized building blocks, and *constraints* acting against the variation of the character. The operational problem with separated body parts is how to distinguish between an adequate and a less or inadequate 'atomization' of the organism. This problem is at the center of organismic or morphological biology. What is being sought are mechanisms responsible for the creation and maintenance of the evolutionary units in questions. These are locally acting self-regulating mechanisms during the development of the organism that cause the differentiation of the organs. Most of them

are well known: self-assembly, fixation of temporal patterns, and spontaneous pattern formation. Interestingly, these mechanisms differ in their causal role for constructing and maintaining organismic features. There are passive structures as well as actively maintained ones, determined by different causal factors. These results of developmental biology have led to the proposal that there are two quite different regulatory processes responsible for the construction of organic characters and the determination of their structural identity in spite of developmental perturbations: *morphogenetic* and *morphostatic* cellular mechanisms. Research on developmental modularity can explain how to pick the right traits out of such a complex organization as organisms; how, so to speak, to carve nature at its joints.

These results are able to reconcile the existence of apparently solid developmental constraints with apparently variable developmental pathways and are a big step towards a theory of morphological evolution. The modularity concept[2] provides an answer to the problem of how genotypic conditions are represented at the phenotype level (the genotype-phenotype map), and how phenotypic conditions are represented at the level of the organism's fitness (the phenotype-fitness map). Hence the concept of developmental modularity explains how continuity and quasi-independence are achieved, but only, of course, by characters that reflect the real, modular structure of development. Once again, the moral is that a genuinely evolutionary psychology cannot focus on the adaptive advantages of certain phenotypes and leave the genes to take care of the rest. Understanding how the mind grows is critical to determining how it might have evolved.

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[2] It is ironic that two such closely related fields as Narrow Evolutionary Psychology and Evolutionary Developmental Biology should make such different uses of the concept of 'modularity'. NEP has a theoretical argument for the existence of modules: it would be difficult to optimize a mind for any one adaptive problem if the same mind is used to solve many problems. NEP modules are postulated on the basis of thinking about the structure of ancestral environments and evidence for their existence is provided by domain specific effects in cognitive performance. EDB has its own theoretical argument: modules explain how structures can be altered one at a time. But these structures need not (although they can) correspond to single adaptive functions and so must be discovered empirically, rather than via 'adaptive thinking'. Evidence for specific modules can take the form of 'developmental constraints' inferred from comparative biology or of direct evidence about how the phenotype develops. The EDB view of modules makes it obvious that the modular structure of the organism shapes the course of evolution, as well as being shaped by it, whereas the NEP view overlooks this fact, as discussed in Section 3 above.

4.3 Extended Inheritance

What we can conclude from the preceding section is that developmental mechanisms, which are to a certain degree *emergent* mechanisms with respect to their genetic basis, determine where one, quasi-independent evolutionary character ends and the next begins. That leads us to the question of the heritability of such mechanisms: their stability and reliable presence at the next generation. Have we not all learned that only genetic variations are of any interest to evolution since these are the ones that can be picked out by natural selection? How does this leave us with respect to the interaction of evolution and development?

Cosmides and Tooby give a suitably interactivist description of the relationship between genes and environment:

> The cognitive architecture, like all aspects of the phenotype from molars to memory circuits, is the joint product of genes and environment. … [Evolutionary Psychologists] do not assume that genes play a more important role in development than the environment does, or that "innate factors" are more important than "learning". Instead, [Evolutionary Psychologists] reject these dichotomies as ill-conceived. (Tooby and Cosmides, 1997, p. 16)

So far so good. But in practice, this partnership can be very one sided:

> The genes *allow* the environment to influence the development of the phenotype […] genes are simply regulatory elements, *molecules that arrange their surrounding environment* into an organism. … To learn, there must be some mechanism that causes it, the mechanism that causes it must itself be unlearned - must be "innate". (Tooby and Cosmides, 1997, pp. 17-18)

One needs to go a bit further to do justice to gene-environment interaction. Obviously, talk of 'innate mechanisms' only disguises the fact that the mechanism itself has to develop. Even the most fundamental mechanisms have to be constructed by the

controlled expression of gene products. That expression relies on a wide range of causal factors, which is why normal development can be so easily perturbed (of course, most such perturbations are pathological, but so are most perturbations due to mutation.) It is commonly argued that the presence of the right genes must be what explains evolved traits, because genes are the only things organisms inherit from their ancestors. But a principled definition of inheritance does not yield this result (Griffiths and Gray, 2001). Organisms inherit an extended range of resources that interact to reconstruct the organism's life cycle. Some of these resources are familiar--chromosomes, nutrients, ambient temperatures, childcare. Others are less familiar, despite the recent explosion of work on "epigenetic inheritance" (Jablonka and Lamb, 1995). These include chromatin marks that regulate gene expression, cytoplasmic chemical gradients, and gut- and other endosymbionts.

Another important topic in recent biology is the participation of the organism in the construction of its niche (Odling-Smee, 1996). Hence a further aspect of inheritance is the local physical environments, altered by past generations of the same species and other species as well as the organism's own activities. Many of these inherited resources have distinctive roles. DNA is unique in acting as templates for protein synthesis. Membranes are unique in acting as templates for the assembly of proteins into more membrane. Chemical traces from foraging play a characteristic role in diet choice in many rodents. These empirical differences between what DNA does and what other factors do are real and important, but do not map onto any deeper, more metaphysical distinctions, such as that between form and matter or, as Cosmides and Tooby suggest, between factors which do the arranging and factors that are arranged.

4.4. Development as adaptation, or giving genes a break

Extended inheritance is an important element of the explanation of evolved traits. But it also serves to break down unnecessarily sharp distinctions between evolutionary adaptations and ontogenetic adaptation to the current environment. Narrow Evolutionary Psychology claims to have done this too, via the idea that development explores a tree of

possibilities encoded in the genes, but this simply creates a sharp dichotomy between encoded outcomes triggered by the environment and outcomes that are not encoded and hence not subject to evolutionary explanation at all. The role of development in the Narrow Evolutionary Psychology is little more sophisticated than it was in the 'open program' model of the 1940s: Genes do not just code for a suitable reaction to a particular stimulus, they code for an 'open' program that has a range of suitable reactions, each adapted to one of several previously experienced environments. The 'program' must foresee all possible problems with ready solutions as appropriate reactions. If that were what cognitive development is like, then we would have a new evolutionary paradox: why did evolution invent complex and costly features like a mind and an extended period of post-natal development, while making no more use of them than to detect a few cues and respond with predetermined solutions to previously solved problems?

In the human case, we are dealing with the evolution of 1) a massively extended period of development - *childhood*, 2) an extended organ for the processing of ad hoc information - *cognition*, 3) the ability to form and perform complex social interaction - *sociality*, and 4) the capacity to produce a new kind of environment made out of rites, public knowledge and tradition and preserved by new ways of transmission- *culture*. According to Narrow Evolutionary Psychology, or at least according to its oft-proclaimed account of the role of genes and environment in development, these processes do not allow humans to cope with genuinely novel environments at all - they merely serve to choose from a suite of pre-specified adaptations on the basis of environmental cues.

In contrast to Narrow Evolutionary Psychology, the traditional view is that the function of these processes is to react to all sorts of 'adaptive problems' on the spot without the necessity to wait for multi-generational feedback to build another option into the developmental program. Development, cognition, and culture, it is argued, have been adapted for creating novel *adaptive* behavior. But traditionally, this new domain of adaptation has been seen as isolated from explanation by natural selection, as Narrow Evolutionary Psychology constantly points out and rails against. Embracing extended inheritance and a richer model of the role of non-genetic resources in development makes

it possible to accept the traditional view of the role of cognition and culture without drawing a sharp line between adaptation by natural selection and adaptation via cognition and culture. The new mechanisms of adaptation can be 'tweaked' and biased in all sorts of ways by adaptive evolution, as in, to choose the simplest example, the phenomenon of 'prepared learning' (Seligman and Hager, 1972). Evolution for flexibility can interact with evolution for bias and for stronger forms of canalization in many combinations, and evolutionary explanations of cognitive traits can take equally many forms.

4.5   Selection, Order and Adaptation

Adaptations are the accumulated output of selection, and selection is the *single significant anti-entropic ordering force* orchestrating functional organic design. (Tooby and Cosmides, 1992, p. 55, our emphasis)

Thus, chance and selection, the two components of the evolutionary process, explain different types of design properties in organisms, and all aspects of design must be attributed to one of these two forces. *Complex functional organization is the product and signature of selection.* (Tooby and Cosmides, 1992, p. 63, our emphasis)

These are typical statements of the idea that order must either be explained by selection or put down to mere chance. Random mutation and natural selection are the only possible explanations of order. Sometimes, this seems to be a sort of definition. If a trait's function is the role for which it has been selected and an adaptation is an outcome of natural selection, then it is trivially true that natural selection is the sole explanation of function and adaptation in nature. But this is an empty victory, since on these definitions there is much order (negentropy) in nature that is not obviously 'functional' or 'adaptive'. Narrow Evolutionary Psychology tries to obscure this by redefining negentropy itself as functional design (!), but this is profoundly unhelpful in understanding either negentropic processes in general or natural selection in particular. In this section we argue that not

only do other negentropic forces exist, their existence is part of what makes possible natural selection and the further order that it produces.

The claim that nature is mainly entropic is a common prejudice and rests on a simple misinterpretation of the second law of thermodynamics. The growing science of complexity and complex adaptive systems has taught us that only *closed* systems are progressively chaotic (equilibrated), whilst *open* systems (including all living systems) are far-from-equilibrium and dissipative. The main neg(ative) entropic force in nature is *self-organization*, the exploitation of external energy for the production of order. The main mechanism is the production of energy gradients and the constrained release of energy: critically interacting components naturally tend to self-organize, and many of these self-organizing systems are able to perform physical work by means of internal *constraints* on the release of energy. Constraints are hyperstable structures sensitive to – and hence containing information about - relevant displacements from equilibrium that can be useful sources of energy from which work can be extracted (wind blowing or water flowing in on direction, concentrated heat sources like the sun, food as high-energy cluster of matter, etc.). They allow the constrained or directed release of this energy into a small number of degrees of freedom for the production of order (for example further constraints). Hence *constraints in general are anti-entropic forces in nature,* and natural selection – or external constraint - is just one of them.

Natural selection occurs whenever there are individuals with differential fitness. The causal processes involved here, obviously, are the systematic contributions of heritable traits to the reproduction of individuals. So natural selection is the overall outcome of a range of causal processes taking place at the level of the organism and causing survival and reproduction. Selection itself - differential survival and reproduction - is a widespread phenomenon not only in biology but also in the physical, chemical or cultural realms, but it rarely seems to lead to the increasing adaptive complexity that is so striking in the biological realm. So the question arises: what is so special about organisms that selection upon them results in adaptive evolution? First, they are open, dissipative systems extracting order from the environment by means of self-organization that allows

them to maintain and at the same time adapt themselves to internal and external perturbation, and to reproduce themselves. These distinctive capacities are those that several recent authors have claimed as the defining properties of *living* systems (Christensen and Hooker, in press, Kauffman, 1993; Hooker, 1995; Weber and Depew, 1996). From this perspective, self-organization is not an alternative force competing with natural selection but the complementary force that creates systems capable of achieving adaptive complexity through evolution by natural selection. Self-organization can act locally as a force that resists selection - an internal fitness function drives the system to a particular attractor in its state space and holds it there in the face of mutation, thus preventing a response to selective forces. But when we look at the process on a larger scale, natural selection, by maximizing some external fitness function, is acting to move a population of systems in a population-level state space by choosing between individuals sitting at different attractors. Selection requires alternative, stably self-organized systems to choose between on the basis of the resultant (phenotypic) properties. Applying external fitness criteria is certainly important in producing what we call complex adaptation. However, at that stage a lot of necessary work on the way to a functioning organism has already been done by internal fitness criteria guiding the process of self-organization. These internal organizational processes are negentropic, not entropic, contrary to the frequent assertions of Narrow Evolutionary Psychology:

> Finally, of course, *entropic effects of many types* act to introduce functional disorder into the design of organisms. They are recognizable by the lack of coordination that they produce within the architecture or between it and the environment, as well as by the fact that they frequently vary between individuals. Classes of entropic processes include mutation, evolutionary unprecedented environmental change, individual exposure to unusual circumstances, and developmental accidents. (Tooby and Cosmides, 1992, p. 63, our emphasis)

Applying this line of reasoning to classic examples in developmental biology produces quite bizarre results. On what possible account of 'entropy' does perturbing Drosophilia development to produce the bithorax phenotype, either by mutation or by developmental

shock, increase the entropy in the system? A bithorax Drosophila is at least as highly ordered as a wild-type Drosophila. The answer, of course, is an account that mixes up adaptive function and entropy in the phrase 'functional disorder'. But this redefinition is profoundly unhelpful. Selection can sometimes favor increased disorder, as in the evolution of vestigial traits, and order can arise without selection, as complexity theory amply demonstrates. There are any numbers of sound theoretical reasons to keep the concepts of order and functional design distinguished and no reasons we can see to run them together like this.

The application to evolution of complexity theory with its focus on systems dynamics and self-organization could shift our view from natural selection to a more inclusive vision of 'natural construction' by offering tools to integrate organizational dynamics into evolutionary theory. We can re-conceptualize natural selection as a result of the *interaction* of system and environment, and adaptation as the mutual *interactive construction* of the organism and its environment. Evolution can then be understood as change in the constitution and distribution of developmental systems. The developmental system is an organism-environment complex that changes over both ontogenetic and phylogenetic time. There is no need to attribute so much power to an external mover (natural selection) or to an independent internal force (genes and their mutations) that you deprive the organism of all its active control (Oyama, 1992; Stotz, 1999). This makes possible the re-interpretation of organisms as the active source of the emergent properties of life by means of interaction and construction, and marks a shift from focusing on the *products* of processes (like genotypes, traits, or gene frequencies) to the *processes* themselves.

5. Conclusion: Naturalism and 'Design'

There is nothing wrong with focusing on the concept of function. The possession of function and functional organization is indeed a paradigmatic property of living beings. Function, however, treated as a serious theoretical concept rather than a rhetorical frill,

has remained the exclusive domain of biology, psychology and sociology and, of course, the study of human artifacts. This suggests that function is an *emergent property* in need of explanation in terms of more basic organizational principles. A major point of the last section was that function in biology cannot simply be reduced to random mutation and natural selection. It is the role of development to supplement those basics to give an adequate account of the origin of adaptive complexity. Development is needed because the design analogy mischaracterizes evolution. Here lies the deep commonality in the shortcomings of the explanatory strategies of evolutionary theory and traditional cognitive science, and therefore of the Narrow Evolutionary Psychology that brings these two traditions together - they have bypassed development with its nonrandom and contingent processes of organization. Evolution and development are based on nonrandom physical processes that are able to link matter, energy and information to perform autocatalysis, reproduction, and physical work. Like evolution, development is a contingent, historical processes in which one step sets the stage for the next without going beyond that to determine the eventual outcome. This outcome will be the result of an *interactive* and *constructive* process of a system in its relation to its environment.

A properly epigenetic perspective on evolution and cognition should not presuppose the existence of any property that should rather be the subject of explanation. This implies the definition of mind-like behavior without ultimate reference to internal representation, and the definition of life without ultimate reference to teleological function. There is neither a natural designer who predefined the function or meaning of behavior, nor a last representational homunculus at the very end of the process of reference. Life processes are to be explained without reference to an ultimate, teleological function, just as intentionality is to be explained as emerging out of non-intentional processes.
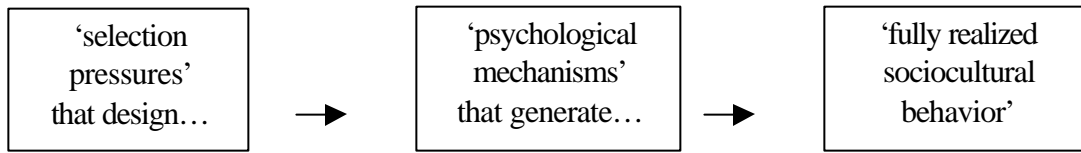
'selection pressures' that design…	→	'psychological mechanisms' that generate…	→	'fully realized sociocultural behavior'

Figure 1. Psychology as the 'missing middle.' See (Cosmides et al., 1992: 6)
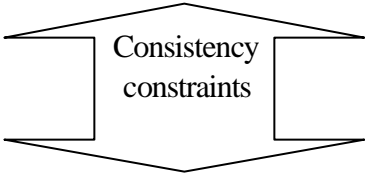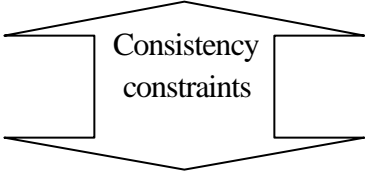
Figure 2. The three 'Marrtian' levels of analysis in cognitive science.
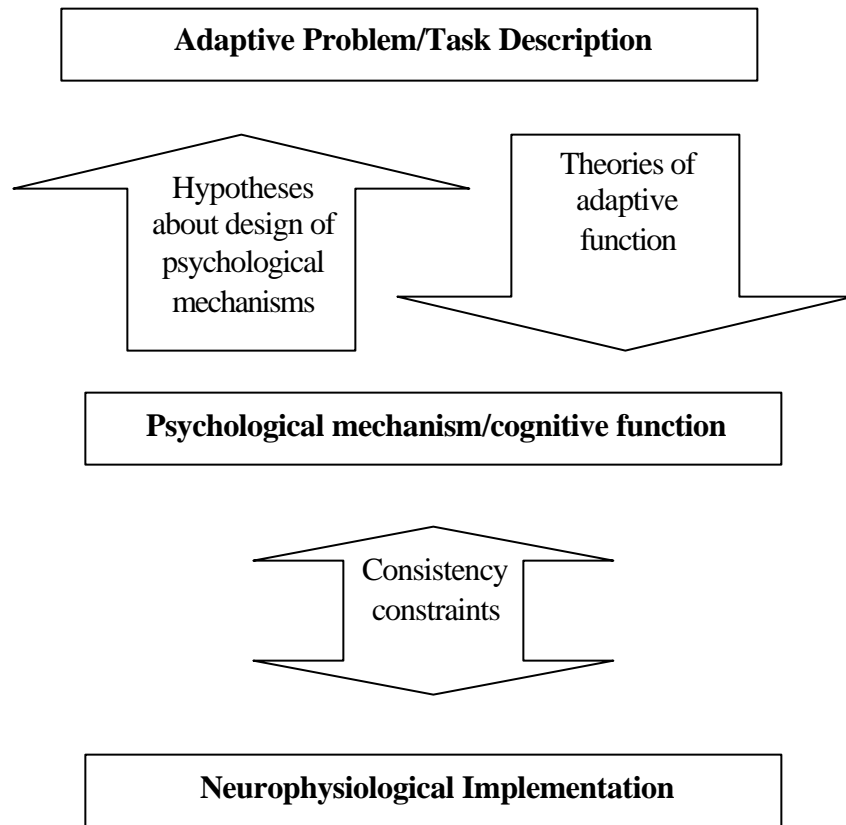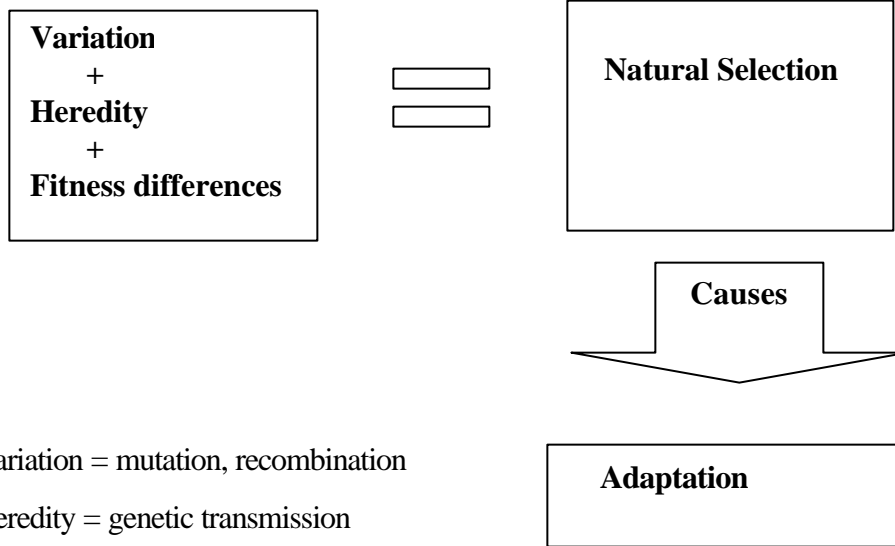
Figure 3. Evolutionary reasoning from one Marrtian level of analysis to another. Adapted from (Cosmides et al. 1992: 10) and (Tooby and Cosmides 1997: 2).

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┌─────────────────────────┐          ┌─────────────────────────┐
│  Variation              │   ▭      │                         │
│      +                  │   ▭      │   Natural Selection     │
│  Heredity               │          │                         │
│      +                  │          │                         │
│  Fitness differences    │          │                         │
└─────────────────────────┘          └─────────────────────────┘
                                                  │
                                              Causes
                                                  ▼
                                      ┌─────────────────────────┐
                                      │                         │
                                      │   Adaptation            │
                                      │                         │
                                      └─────────────────────────┘
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- Variation = mutation, recombination
- Heredity = genetic transmission
- Fitness = propensity to survive and reproduce,
- Natural Selection = differential survival and reproduction
- Adaptation = the outcome of natural selection

Figure 4. The received view of evolution by natural selection

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